

Tradeoffs from Hedging Oil Price Risk in Ecuador

Sudhakar Satyanarayan

Eduardo Somensatto

The benefits in risk-reduction
from hedging Ecuadorian oil
and the opportunity costs of
hedging

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Summary findings

The oil sector is critical to Ecuador's economy, contributing about 17 percent to the country's GDP. Ecuador began exporting crude oil in 1972 and over the past two and a half decades oil has become the country's most important sector. It is controlled by the government through the public enterprise, PETROECUADOR, which serves as the holding company for all state-owned petroleum operations.

Movements in oil prices are of major concern to the government, and forecasts of oil prices are built into the government budget. Ecuador's macroeconomic performance depends on the oil sector's performance; shocks to the sector have economywide repercussions.

Satayanarayan and Somensatto investigate methods to reduce risk for the country's oil exports through hedging in futures markets. They find that hedging Ecuadorian oil has significant potential for risk reduction.

After simulating ex-ante cross hedges for 1991-96, they find that in each case ex-ante hedging effectively reduces risk. They calculate the tradeoffs between return and risk from hedging and find that for a risk-minimizing short hedger, a 1-percent reduction in risk would cost a reduction in return of 0.65 percent.

This paper — a product of the Country Operations Division, Country Department III, Latin America and the Caribbean — is part of a larger effort in the department to provide policy advice to member countries. Copies of the paper are available free from the World Bank, 1818 H Street NW, Washington, DC 20433. Please contact Eduardo Somensatto, room H5-103, telephone 202-473-0128, fax 202-477-8518, Internet address esomensatto@worldbank.org. June 1997. (18 pages)

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TRADE-OFFS FROM HEDGING OIL PRICE RISK IN ECUADOR

Sudhakar Satyanarayan
Dept. of Finance, Rockhurst College
1100 Rockhurst Road
Kansas City, MO 64110
Tel: (816) 501-4562

and

Eduardo Somensatto
Europe and Central Asia Region, Southeastern Europe Department
World Bank, Washington, D.C. 20433
Tel: (202) 473-0128

I. INTRODUCTION

The oil sector is a critical sector of the Ecuadorian economy contributing about 17% to the country's GDP. Ecuador began exporting crude oil in 1972 and over the last two and a half decades the oil sector has emerged as the country's most important sector. The oil sector is controlled by the government through the public sector enterprise, PETROECUADOR, which serves as the holding company for all state-owned petroleum operations. Movements in oil prices are of major concern to the government and forecasts of oil prices are built into the government budget. The performance of the oil sector critically affects Ecuador's macroeconomic performance and shocks to this sector has economy wide repercussions.

The volatility of the world oil market since the OPEC oil price shocks of the 1970's has resulted in oil export dependent countries like Ecuador facing a considerable degree of macroeconomic risk. Between 1973-81 when Ecuador first emerged as an oil exporter, real GDP grew at an annual average rate of 6.1%. During much of the 1980's, oil prices declined substantially. Over the 1985-86 period, Ecuador lost U\$900 million equivalent to about 8% of GDP. Declining oil revenues resulted in large public sector deficits and a worsening balance of payments situation. The effect of the oil price decline was that between 1981-91, GDP growth averaged about 2.1 %, less than half the growth rate before the oil boom¹. Ecuador's dependence on oil is such that even minor oil price declines have had a substantial cumulative adverse impact on Ecuador's macroeconomic performance.

Developing countries like Ecuador have sought to achieve export revenue stabilization through International Commodity Agreements with importing nations. These agreements have

¹ The source of these figures are **Ecuador: Policy Options for the Rest of the 1990's**, Report No.11161-EC, Country Operations Dept. IV, World Bank.

however not been successful. Other methods such as stabilization funds, contingent financing and export diversification have also not been successful in stabilizing export revenues.

An alternative approach to stabilizing export revenues is to use market-based risk management tools such as futures hedging. Though futures hedging cannot insulate exporters from a long term secular decline in commodity prices, they are effective in managing short term price risk. Using futures markets for hedging is a notion that is just now beginning to gain acceptability among developing countries. The New York Mercantile Exchange (NYMEX) estimates that developing countries are increasingly holding a higher percentage of the total open interest in crude oil futures. Since the Gulf war countries like Mexico, Brazil and Chile are regular users of the oil derivatives markets (see Claessens and Varangis (1995)).

The objective of this paper is to assess the risk management prospects for hedging Ecuadorian oil. We develop a portfolio model of hedging and use it to evaluate the costs and benefits of different hedging strategies. Our paper shows that there are effective risk reducing strategies available to Ecuadorian policy makers that would have reduced the variance of Ecuadorian oil revenues over time. While these strategies may necessitate foregoing unexpected gains, they would have prevented unanticipated short term losses. We provide estimates of the costs and benefits of different hedging strategies that may aid in policy formulation.

II. PRICE VOLATILITY, STATIONARITY, AND BASIS RISK

The bulk of international trade in crude oil involves light to medium crude (API gravity of 30⁰ to 40⁰). Ecuadorian oil (Oriente) is classified as light crude. Ecuador's monthly oil export prices over the Jan.88-Dec.96 period is shown in Figure 1. The average monthly export price (per barrel) for Ecuadorian crude over this period was \$15.92 with a standard deviation of \$3.45 and an associated coefficient of variation of 21.67%. This is a high degree of volatility.

Before turning to the issue of hedging effectiveness, the time series properties of export (spot) prices and futures prices need to be investigated. The spot and futures prices of most commodities are generated by stochastic processes that are nonstationary (i.e. these prices are random walks). The practical implication of nonstationarity is that past prices cannot be used in predicting future prices. Moreover, transitory and permanent shocks cannot be distinguished from one another. From an econometric viewpoint, nonstationarity is problematic since estimated parameters are unstable and a regression on nonstationary variables leads to spurious results (see Granger and Newbold (1974)). Thus, a nonstationary series must be transformed into a stationary series before any inferences can be drawn from it. The simple logic for requiring stationarity is that models inferred from stationary series are also stationary or stable. In general, a nonstationary series can be transformed into a stationary series by differencing. Table 1a reports the results of a Dickey-Fuller (D-F) test for nonstationarity on the **levels** and **first differences** of both spot and futures prices. The D-F test results confirm that both spot and futures prices are nonstationary in levels but stationary in first differences. Thus, regressions must be constructed in terms of the stationary, first differenced variables.

FIGURE 1
EXPORT PRICES & FUTURES PRICES

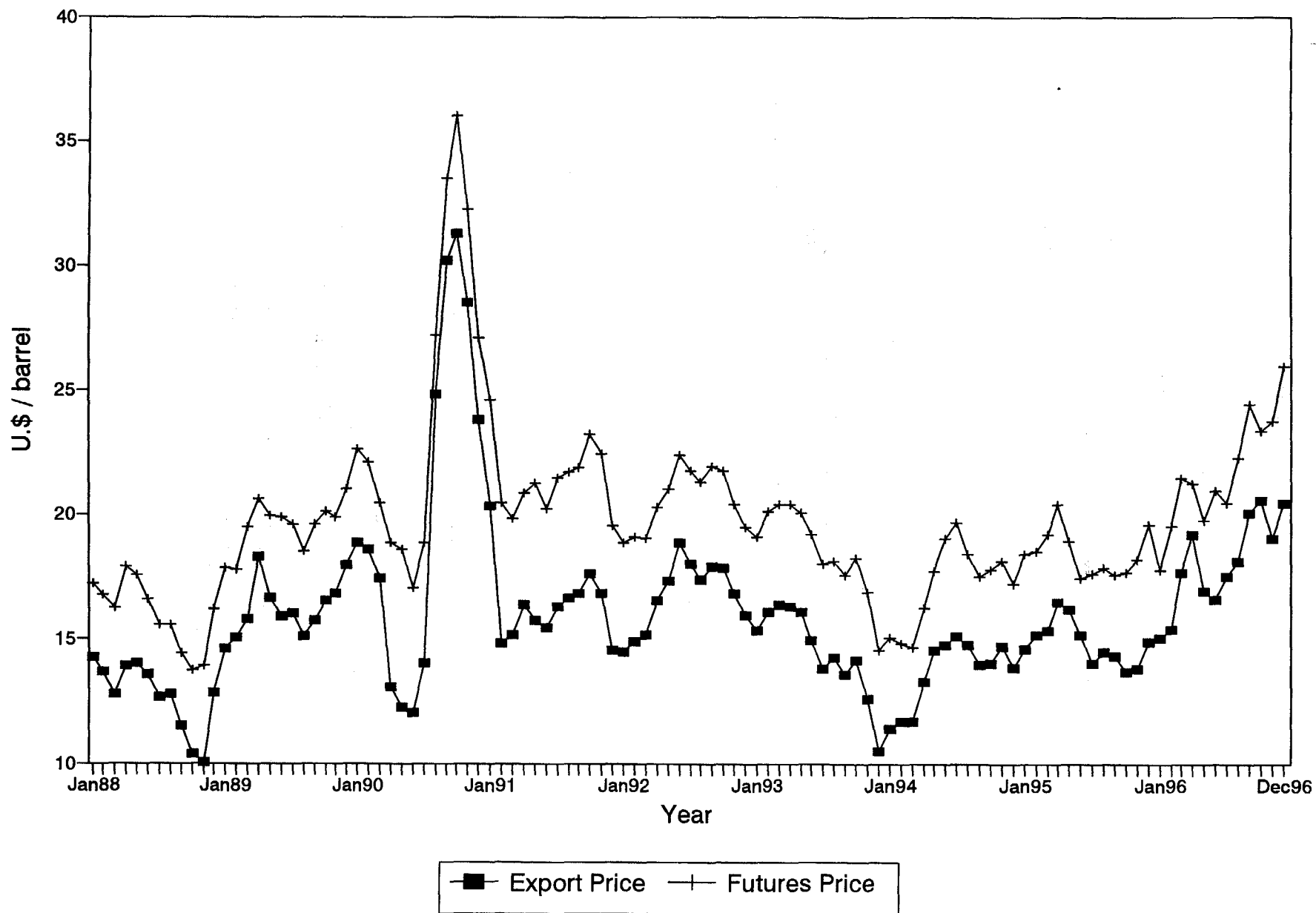


Table 1a
Tests of Stationarity (Jan.1988-Dec.1996)

Variable	Dickey-Fuller D-F (statistic)	Augmented D -F
(1) Spot Price (Levels)	-2.69	-2.08 (6 lags)
(2) Futures Price (Levels)	-2.32	-1.97 (6 lags)
(3) Spot Price (Differences)	-6.57**	-5.06**(6 lags)
(4) Futures Price (Differences)	-6.51**	-5.25**(6 lags)

Note: The critical value of the D-F statistic for 100 observations is -3.45. ** indicates significance at the 95% level.

Table 1b
Test of Basis Risk (Jan.1988-Dec.1996)

Regression	α	β	R^2	D-W
$\Delta S_t = \alpha + \beta \Delta F_t$	-.02 (-.28)	.96** (21.41)	.81	2.37

Notes:

1. $\Delta S_t = S_t - S_{t-1}$, $\Delta F_t = F_t - F_{t-1}$
2. D-W: Durbin-Watson Statistic
3. ** indicates significance at the 95% level . T-statistics are in parentheses.
4. The stationarity test involves the following regression:

$$\Delta X_t = \alpha + \beta X_{t-1} + \sum_{i=0}^p \delta_i \Delta X_{t-i} + e_t$$

If $\delta_i = 0$, $\forall i$ this is referred to as the Dickey Fuller (D-F) test. If $\delta_i \neq 0$, $\forall i$ this is called the Augmented Dickey Fuller (ADF) test. The optimal lag length, p , is chosen using Akaike's Information Criterion (AIC); p is the value that minimize's AIC.

If β is significant, the null hypothesis of nonstationarity is rejected. A significant D-F test statistic thus rejects the null, implying stationarity. Note that the spot and futures prices in levels are non-stationary but the spot and futures prices in first differences are stationary.

The world's largest oil futures market is the NYMEX². The NYMEX crude oil futures contract which was introduced in March 1983 is based on pipeline delivery of 1000 barrels of West Texas Intermediate (WTI) crude in Cushing, Oklahoma. The quality of Ecuadorian Oriente is similar but not identical to WTI crude. If the quality of the spot (cash) commodity is identical to the quality of the commodity specified in the futures contract, the usual recommendation is to hedge all of the spot commodity since the spot and futures price in this case tend to be highly correlated. This type of hedge is called a "naive" hedge. But since Ecuadorian Oriente differs from WTI crude, the effectiveness of "cross-hedging" Ecuadorian crude using the WTI futures contract needs to be determined.

Since Ecuadorian crude differs from the WTI crude specified in the futures contract there will be some divergence between the time series behavior of Ecuadorian spot prices and WTI futures prices. This divergence is called "basis" risk. In general, the greater the correlation between spot and futures prices, the more effective the hedge. Since R-square (R^2) is essentially a measure of correlation, hedging effectiveness is measured by R^2 , and basis risk by $1-R^2$. Table 1b reports the results of a regression of spot price changes on (nearby) futures price changes. The R^2 of .81 and basis risk of .19 indicates that Ecuadorian crude can be hedged using the WTI futures contract.³

² Other exchanges that trade crude oil and petroleum futures are the IPE (International Petroleum Exchange), SIMEX (Singapore International Monetary Exchange) and ROEFEX (Rotterdam Exchange). Liquidity is however highest in the NYMEX. Besides liquidity considerations, Latin American countries prefer hedging on the NYMEX because of time zone and trading hour considerations.

³ Note that the regression is constructed in terms of stationary or differenced variables. Hedging effectiveness is sometimes measured as the R^2 of a regression of price levels. This would be incorrect in our case given that we have determined spot

III. RISK AVERSION AND RETURN-RISK TRADE-OFFS

To illustrate the benefits of hedging, a simple framework is presented here depicting the hedging decision as a portfolio selection problem in which the hedger selects the optimal proportions of unhedged (spot) and hedged (futures) output⁴. The portfolio can then be represented as:

$$ER_p = Q_u E(S_{t+1} - S_t) + Q_h E(F_{t+1} - F_t) \dots \dots \dots (1)$$

where:

ER_p = Expected return on the hedged portfolio

Q_u = Unhedged (spot) output or output available for export

$E(S_{t+1} - S_t)$ = Expected change in the Ecuadorian export price from time t to $t+1$

Q_h = Hedged output

$E(F_{t+1} - F_t)$ = Expected change in the futures price from time t to $t+1$

At time period t , S_t and F_t are known but S_{t+1} and F_{t+1} are unknown; S_{t+1} and F_{t+1} are thus random variables.⁵

and futures price levels to be nonstationary.

⁴ The model here is similar to that in Satyanarayan, Thigpen and Varangis (1993).

⁵We have not incorporated costs into the model. These costs include brokerage fees and the opportunity cost of holding a margin account - i.e., the difference between the interest bearing notes of the margin account and investing somewhere else. However, these costs are considered very small.

The issue to be determined is if the country is better off not hedging as compared to some hedging. Here we will consider only the use of a "short-hedge" to insure against price declines. (A short hedge is one in which the hedger **sells** futures contracts). In a short hedge, a long position in the spot market ($Q_u > 0$) is offset by a short position in the futures market ($Q_h < 0$). Let $h = (Q_h / Q_u)$. If the value of Q_u is set equal to 1, h can be interpreted as the hedge ratio - the percentage of the spot or cash position that is hedged in the futures market. Thus for a short hedger,

$$ER_p = E(S_{t+1} - S_t) - h E(F_{t+1} - F_t) \dots \dots \dots (2)$$

If the portfolio is completely hedged, that is, each unit in the spot market is hedged with a unit of futures, then $h = 1$ (i.e. naive hedge). If $h = 0$, then there is no hedging and the expected return on the portfolio is simply equal to the return on the spot market.

The Variance (Var_p) or risk of the portfolio is given by:

$$Var_p = Var(S) + h^2 Var(F) - 2 h cov(S,F) \dots \dots \dots (3)$$

where:

$Var(S)$, $Var(F)$ = variance of spot and futures price changes

$cov(S,F)$ = covariance between spot and futures price changes

The expected utility (EU) function of the Ecuadorian hedger is a function of the expected return (ER_p) and variance of the portfolio (Var_p). Thus,

$$EU = E(R_p) - \lambda Var_p \dots \dots \dots (4)$$

where λ is a risk aversion parameter. Higher (lower) values of λ imply higher (lower) levels of risk aversion. The model above is a mean-variance model (see Markowitz (1959)) and implicitly assumes that the hedger has a quadratic utility function or that returns are normally distributed.⁶ The optimization problem is to select the hedge ratio which will maximize EU. Thus,

$$\partial EU / \partial h = - E(F_{t+1} - F_t) - 2\lambda h Var(F) + 2\lambda cov(S, F) = 0$$

Solving for the optimal (utility-maximizing) hedge ratio, h^{**} , from the above gives:

$$h^{**} = [cov(S, F) / Var(F)] + [(F_t - E(F_{t+1})) / 2\lambda Var(F)] \dots \dots \dots (5)$$

Let $h^* = [cov(S, F) / Var(F)]$. The above may then be rewritten as:

$$h^{**} = h^* + ([F_t - E(F_{t+1})] / [2\lambda Var(F)]) \dots \dots \dots (6)$$

⁶ Quadratic utility functions raise several theoretical problems (see Arrow, 1971) but work by Levy and Markowitz (1979) and Kroll, Levy, and Markowitz (1984) suggest that the assumption of quadratic utility is a reasonable empirical approximation.

With infinite risk aversion $\lambda \rightarrow \infty$ and the second term disappears. Therefore, for a risk minimizer the first term in the equation above, h^* , is the only relevant one. The variable h^* is called the hedging component and is equivalent to the **risk-minimizing hedge ratio**. *Note that h^* is the slope coefficient of an OLS regression of spot price changes (dependent variable) on futures price changes (independent variable)*. With infinite risk aversion, the optimal or utility maximizing hedge ratio is the same as the risk minimizing hedge ratio (i.e. $h^{**} = h^*$).

The second term in (6) is called the speculative component and implies that the greater the level of risk aversion, the smaller the speculative component. The speculative component is however positively related to the "bias" ($F_t - E[F_{t+1}]$) between the current and the expected futures price. The speculative component essentially captures the effect of short hedging on expected returns.⁷ If the expected futures price is less than the current futures price, the hedger benefits from selling ahead more of his output.

Table 2 reports ex-ante (before the resolution of uncertainty) and ex-post (after the resolution of uncertainty) risk minimizing hedge ratios and contrasts the performance of four portfolios - unhedged, naive, ex-ante hedged and ex-post hedged for the years 1991-96. We assume that hedges are placed at the beginning of each year by buying the one year crude oil futures contract on the NYMEX and continued until December, a month before the contract

⁷ Equation 6 also implies that if the current futures price is an unbiased estimate of the expected futures price (i.e. $F_t = E[F_{t+1}]$), the speculative component in h^{**} disappears and $h^{**} = h^*$. Thus in an unbiased futures market, the risk-minimizing hedge ratio is equal to the optimal hedge ratio. Also, with infinite risk aversion the optimal hedge ratio is independent of this bias. See McKinnon (1967) and Rolfo (1980).

TABLE 2
Performance of Hedged and Unhedged Portfolios (1991-1996)

Period	Portfolio	Hedge Ratio	Portfolio Return (US\$/barrel)	Portfolio Variance	Risk Reduction
1991 Hedge					
Jan 88 - Dec 90	Unhedged	$h=0$	-.7758	4.10	-
	Naive	$h=1$	-.5558	1.52	63%
	Ex-Ante Hedged	$h=1.03$	-.5492	1.48	64%
Jan 91 - Dec 91	Ex-Post Hedged	$h=1.64$	-.4150	1.05	74%
1992 Hedge					
Jan 89 - Dec 91	Unhedged	$h=0$	.1192	.7483	-
	Naive	$h=1$	.1075	.1850	75%
	Ex-Ante Hedged	$h=1.05$	.1069	.1701	77%
Jan 92 - Dec 92	Ex-Post Hedged	$h=1.62$	.1003	.0888	88%
1993 Hedge					
Jan 90 - Dec 92	Unhedged	$h=0$	-.4508	.7912	-
	Naive	$h=1$	-.2300	.1938	76%
	Ex-Ante Hedged	$h=1.04$	-.2212	.1820	77%
Jan 93 - Dec 93	Ex-Post Hedged	$h=1.53$	-.1130	.1123	86%
1994 Hedge					
Jan 91 - Dec 93	Unhedged	$h=0$	.2783	.5504	-
	Naive	$h=1$	.2275	.4143	25%
	Ex-Ante Hedged	$h=1.05$	.2250	.4166	24%
Jan 94 - Dec 94	Ex-Post Hedged	$h=.89$	.2331	.4123	25%
1995 Hedge					
Jan 92 - Dec 94	Unhedged	$h=0$	.0850	.5796	-
	Naive	$h=1$	-.0742	.3392	41%
	Ex-Ante Hedged	$h=.88$	-.0551	.3189	45%
Jan 95 - Dec 95	Ex-Post Hedged	$h=.76$	-.0360	.3120	46%
1996 Hedge					
Jan 93 - Dec 95	Unhedged	$h=0$	.4650	1.8134	-
	Naive	$h=1$	-.0658	2.0624	-14%
	Ex-Ante Hedged	$h=.76$	.0616	1.6748	8%
Jan 96 - Dec 96	Ex-Post Hedged	$h=.43$	.2367	1.48	18%

expires.⁸ The ex-ante risk minimizing hedge ratios in Table 2 are estimated using information available only up to the period in which the hedge was placed. Thus, the 1991 hedge is estimated using information available only upto Dec. 1990⁹. The ex-post hedge on the other hand is estimated using the actual spot and futures prices that prevailed over the hedge period. The ex-post portfolio is therefore a benchmark to compare the performance of the other hedges since the ex-post hedge is based on complete information and thus yields the maximum amount of risk reduction.

The results in Table 2 show that in every one of the hedges the variance or risk of the unhedged position exceeded the risk of the ex-ante hedged position. The risk reduction benefits of the ex-ante hedges¹⁰ range from a reduction in risk of 77% for the 1992 and 1993 hedges to 8% for the 1996 hedge. Thus, there are clearly substantial risk reduction benefits from hedging Ecuadorian oil. Notice also that the naive portfolio is less risky than the unhedged portfolio in all hedges except the 1996 hedge. For the 1996 hedge, a naive strategy would have actually resulted in *increasing* rather than decreasing portfolio variance. This simply underscores the fact that naive hedges are not appropriate for hedging Ecuadorian oil since the level of basis

⁸ There is no reason as to why the timing and duration of the hedges cannot be different from that assumed in our paper. We chose the one year contract over a shorter contract, in order to provide simulation results over a longer period.

⁹ In estimating the ex-ante hedge ratios, we use information up to three years prior to the period in which the hedge is placed. This is to ensure that only relatively recent information is used in constructing the ex-ante hedge ratios.

¹⁰The percentage reduction in risk ($1 - [\text{Var}(\text{Hedged})/\text{Var}(\text{Unhedged})]$) is identical to the coefficient of determination, R^2 , in a regression of spot price changes (dependent variable) on futures price changes (independent variable). See Ederington (1979) for a detailed derivation of this result.

risk is high.

An aspect of hedging that does not receive much attention is the fact that hedging carries an opportunity cost in terms of foregone returns. Whether the hedger considers these costs reasonable or not depends upon the hedger's degree of risk aversion. We turn now to a discussion of these costs and the effect of risk aversion on the hedging decision.

We estimated ex-post optimal hedge ratios at different levels of risk aversion using the 1994 futures contract as an example. Table 3 reports optimal hedge ratios at different levels of risk aversion and associated return and risk levels. For values of λ between 100 and infinity, the optimal hedge ratio is essentially constant implying that for these values of risk aversion the speculative component is insignificant¹¹. Thus, it seems that the optimal hedging strategy is not significantly different for reasonable levels of risk aversion. At values of λ equal to or lesser than .10, the results imply that Ecuador should buy rather than sell futures (i.e. negative values of h^{**} imply a long position in futures). This is not surprising in view of the relation that existed between F_t and $E(F_{t+1})$ over the life of the 1994 contract. Over the hedge period, the mean value of $(F_{t+1}-F_t)$ was equal to .0508 (US\$/barrel). Given that the expected futures price, on average, exceeds the current futures prices over the life of this contract, the recommendation is to go net long in futures at lower levels of risk aversion to profit from this price bias.

We calculated portfolio returns and variances for hedge (h) ratios between 0 and 1. These results are reported in Table 4 and graphed in Figure 2. Figure 2 is a mean-standard deviation portfolio opportunity frontier and depicts the return and risk trade-offs from hedging

¹¹ This result is similar to Rolfo's (1980) result on optimal hedging for cocoa producing countries and Ouattara, Schroeder, and Sorenson's (1992) work on coffee hedging for Côte d'Ivoire.

Table 3
Optimal Hedge Ratios, Portfolio Return and Risk at Different Levels of Risk Aversion

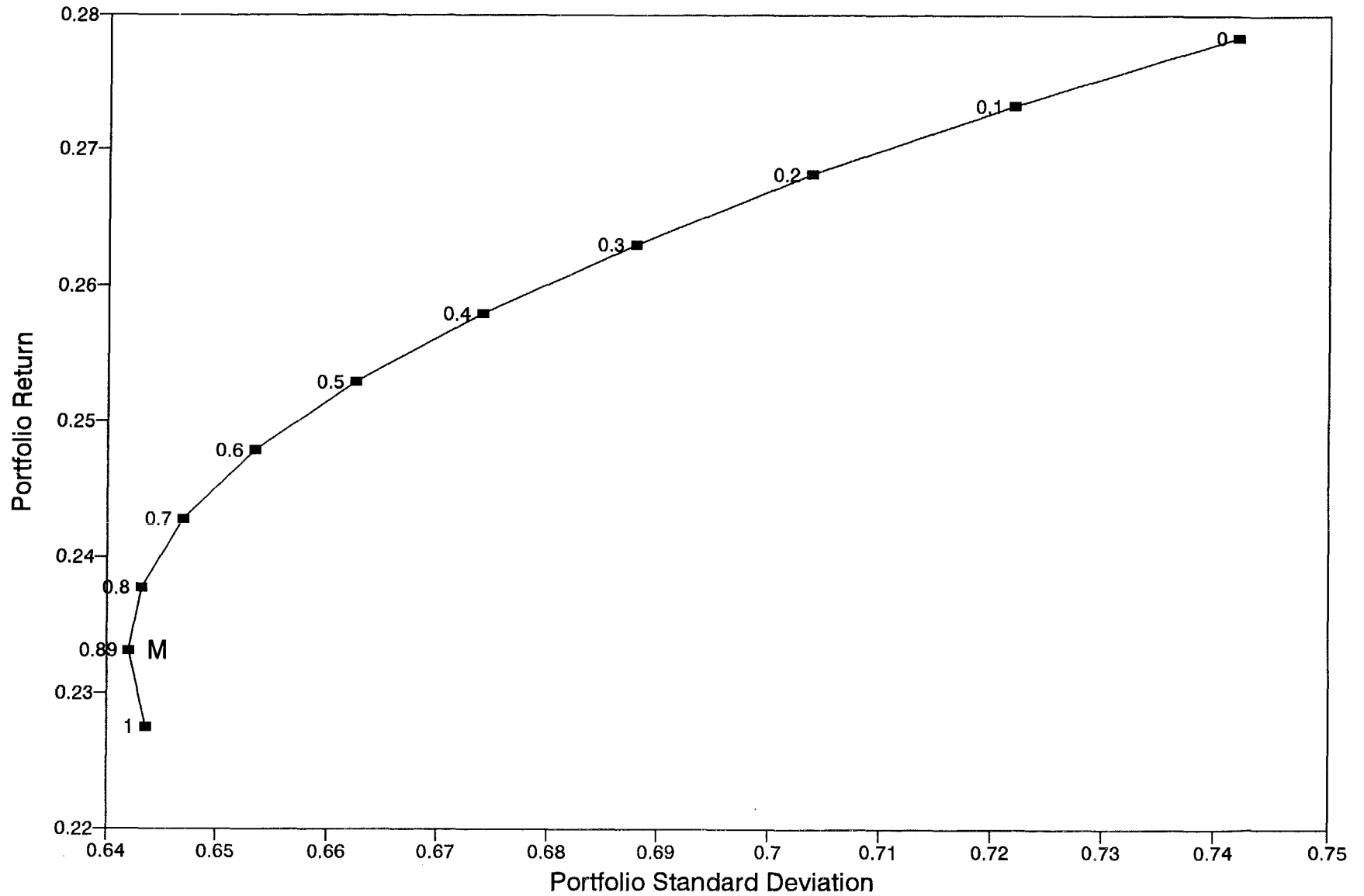
Risk Aversion Parameter λ	Optimal Hedge Ratio h^{**}	Portfolio Return (US\$/barrel)	Portfolio Standard Deviation
∞	.89	.23	.64
10,000	.889	.23	.64
1,000	.889	.23	.64
100	.888	.23	.64
10	.875	.23	.64
1	.743	.24	.65
.10	-.574	.31	.89
.01	-13.75	.98	6.14
.001	-145.54	7.68	61.01
.0001	-1463.43	74.67	610.07

Table 4
Risk-Return Trade-Offs

Optimal Hedge Ratio h^{**}	Implied Risk Aversion Parameter	Portfolio Return	Portfolio Variance	% Reduction in Return	% Reduction in Risk	Cost
0	.1645	.2783	.5504	-	-	-
.10	.1853	.2733	.5212	1.8	5.3	.34
.20	.2122	.2682	.4954	3.7	10.0	.37
.30	.2482	.2631	.4731	5.5	14.0	.39
.40	.2988	.2580	.4543	7.3	17.5	.42
.50	.3755	.2529	.4390	9.1	20.3	.45
.60	.5049	.2478	.4271	11.0	22.4	.49
.70	.7707	.2428	.4187	12.8	23.9	.53
.80	1.6270	.2377	.4138	14.6	24.8	.59
.89*	∞^*	.2331*	.4122*	16.3	25.1*	.65*
.90	-14.64	.2326	.4123	16.4	25.1	.66
1.00	-1.33	.2275	.4143	18.3	24.7	.74

Note: * indicates values associated with the minimum-variance portfolio.

FIGURE 2
RETURN-RISK TRADE-OFFS FROM HEDGING



Note: The numbers on the portfolio opportunity frontier refer to hedge ratios.
M stands for the minimum risk portfolio

Ecuadorian oil. The highest return and the highest risk (standard deviation) are associated with the unhedged portfolio ($h=0$). The minimum risk portfolio corresponds to Point M with an associated return of .2331 (U\$/barrel) and a standard deviation of .642 (variance of .4122). In between the hedge ratios of 0 and .89, lie successive portfolios corresponding to lower risk but also lower return. Note that portfolios on the negatively sloped portion of the opportunity set can be eliminated. These portfolios are inefficient because for the same risk, portfolios on the positively sloped portion yield a higher return.

Figure 2 illustrates the basic policy dilemma faced by the hedger. The fundamental issue is if it is worth foregoing the unhedged rate of return and insuring against possible oil price declines by accepting a lower rate of return. The decision to hedge is influenced by the level of risk aversion. Other important considerations in the hedging decision is the cost of the structural adjustments (fiscal and budgetary adjustments) often undertaken in the face of unexpected price declines.

We also calculated the explicit costs of hedging Ecuadorian oil. Hedging is effective if the decrease in risk is sufficient to compensate the hedger for the decrease in return. We compared the return and variance of the unhedged and hedged positions to calculate a cost elasticity measure as follows:

Cost of Hedging = (Percentage Reduction in Return) / (Percentage Reduction in Variance);

where:

% Reduction in Return = $1 - [(\text{Return of Hedged}) / (\text{Return of Unhedged})]$

% Reduction in Risk = $1 - [\text{Variance (Hedged)} / \text{Variance (Unhedged)}]$

These cost elasticities are shown in the last column of Table 4 and range between .34 to .74, with larger values implying higher costs of risk reduction. The cost associated with the minimum-variance portfolio is .65 which implies that a 1% reduction in risk will result in a .65% reduction in return¹². Whether this is a reasonable cost of risk reduction or not depends upon the hedgers's degree of risk aversion.

IV. CONCLUDING REMARKS

This paper investigates methods to reduce risk for Ecuadorian oil exports through hedging in futures markets. We find that hedging Ecuadorian oil has significant risk reduction potential. We simulated ex-ante cross hedges for 1991-96 and found that in each case, ex-ante hedging was effective in reducing price risk. We calculated the return and risk trade-offs from hedging Ecuadorian oil and found that for a risk minimizing short hedger, a 1% reduction in risk would have cost a reduction in return of .65%.

We conclude that there are risk reduction benefits from hedging Ecuadorian oil. We have provided some estimates of the opportunity costs of hedging that may aid in the hedging decision.

¹² The portfolio opportunity frontier (and thus return-risk trade-offs) will change depending on the levels, variances and covariances of spot and futures price changes and would be different in another period. The results here are indicative of the nature of the trade-offs prevailing in this market.

REFERENCES

- Arrow K., *Essays in The Theory of Risk Bearing*, Amsterdam: North Holland Press, 1971.
- Claessens S. and Varangis P., "Emerging Regional Markets", in *Managing Energy Price Risk*, London: Risk Publications, 1995.
- Ederington L., "The Hedging Performance of the New Futures Markets", *Journal of Finance*, 1979, 34, 157-70.
- Granger, C.W.J. and Newbold P., "Spurious Regressions in Econometrics", *Journal of Econometrics*, 1974, 2, 111-120.
- Kroll Y., Levy H. and Markowitz H., "Mean-Variance Versus Direct Utility Maximization", *Journal of Finance*, 1984, 39, 47-61.
- Levy H. and Markowitz H., "Approximating Expected Utility by a Function of Mean and Variance", *American Economic Review*, 1979, 69, 308-317.
- Markowitz H., *Portfolio Selection*, New York: John Wiley & Sons, 1959.
- McKinnon R., "Futures Markets, Buffer Stocks, and Income Stability for Primary Producers", *Journal of Political Economy*, 1967, 75, 844-861.
- Ouattara K., Schroeder T. and Sorenson L.O., "Potential Use of Futures Markets for International Marketing of Cote d'Ivoire Coffee", *Journal of Futures Markets*, 1992, 10, 113-21.
- Rolfo J., "Optimal Hedging under Price and Quantity Uncertainty: The Case of a Cocoa Producer", *Journal of Political Economy*, 1980, 88, 100-16.
- Satyanarayan S., Thigpen E. and Varangis P., "Hedging Cotton Price Risk In Francophone African Countries", *Policy Research Working Paper*, No.1233, Dec.1993, The World Bank.
- World Bank, "Ecuador: Policy Options for the Rest of the 1990s", *Report No. 11161-EC*, Latin American and the Caribbean Region, Country Operations Department IV, August 1992, The World Bank.

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